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A charcoal-rich horizon at Ø69, Greenland: evidence for vegetation burning during the Norse *landnám*?☆

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ABSTRACT

It is often assumed that the colonisation of Greenland by Norse settlers in c. A.D. 985 had a sudden and dramatic effect on the environment, involving substantial vegetation clearance and environmental degradation. Consequently, it has been argued that charcoal-rich horizons, visible in many sections in Greenland, represent the initial burning of the vegetation by Norse farmers to create land suitable for agriculture. In this study a charcoal-rich layer, visible in a modern drainage ditch beside the Norse farm of Ø69, was analysed using archaeobotany, sedimentary analysis and radiocarbon dating to test the date and formation processes of the horizon. It is demonstrated that the charcoal-rich layer at Ø69 was not derived from *in situ* vegetation burning in the 10th century and concluded that the layer was probably formed by the addition of midden material to the infields around Ø69 in the 13th and 14th centuries cal AD, perhaps as part of a soil amendment strategy. It is argued that caution must be exercised when interpreting charcoal-rich horizons as time-specific chronological markers in palaeoenvironmental sequences in Greenland.

1. Introduction

The Norse settlement of Greenland occurred at the end of tenth century A.D., as part of the final major colonisation episode in the Viking diaspora of the North Atlantic islands (Jones, 1986). It is often assumed that this colonisation, or *landnám* (Old Norse for 'land take'), had a dramatic effect on the environment, involving substantial woodland and vegetation clearance and environmental degradation (Amorosi et al., 1997; Diamond, 2005; Edwards et al., 2008; Fredskild, 1973, 1978, 1981, 1988, 1992a; Jacobsen and Jakobsen, 1986; Jakobsen, 1991; McGovern et al., 1988; Sandgren and Fredskild, 1991). Within this context, it has been argued that charcoal-rich horizons, visible in many sections in Greenland, represent the initial burning of the vegetation by *landnám* farmers to create land suitable for agriculture (Amorosi et al., 1997; Dugmore et al., 2005; Fredskild, 1973, 1988, 1992b; Fredskild and Humle, 1991; Iversen, 1934, 1954; Jacobsen and Jakobsen, 1986; McGovern et al., 1988). Whilst most authors do not rule out the possibility of later settlement events in specific areas of Greenland, it has been argued that these charcoal-rich layers date to the early settlement period (Fredskild and Humle, 1991; Iversen, 1934, 1954; Jacobsen and Jakobsen, 1986; McGovern et al., 1988).

During a survey of the Norse settlement at Ø69 in the Eastern Settlement in Greenland in 2005, a charcoal-rich layer was observed in a modern drainage ditch beside the Norse farm. Given its proximity to the Norse settlement and previous interpretations of charcoal-rich horizons in Greenland, it was hypothesised that this layer may have been created as a result of *landnám* vegetation clearance. The overall research aims of this paper are:

1. To evaluate the date, archaeobotanical composition and the site formation processes of the charcoal-rich horizon at the Norse site of Ø69 in Greenland.
2. To assess the chronological evidence and formation processes of the charcoal-rich layer at Ø69, within the wider context of

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charcoal-rich horizons identified in palaeoenvironmental sequences of Norse date in Greenland.

2. Methods

2.1. Site description

Ø69 is a Norse farm in the Eastern Settlement, which is located at Timerliit, 5 km to the south-west of Igaliku Kujalleq in Southern Greenland (Fig. 1; N 60.85399141, W 45.30485761). The occupation site comprises at least 10 turf and stone built rectangular domestic structures, including a large dwelling, two byres/barns and several other byres/stables/outhouses and extensive midden deposits (Møller and Madsen, 2006; Śmiarowski, 2008). In 2008, the site was cored to define the spatial extent of the midden and to assess the level of organic preservation. Though the local farmer recovered some worked wood fragments from close to the main house structure during the cutting of a modern drainage ditch, only a single poorly preserved bone fragment was recovered during the coring of the midden (Śmiarowski, 2008). The exposed horizons revealed in the drainage ditch transecting the midden were also recorded, but no artefacts or ecofacts were recovered (Śmiarowski, 2008). The results of this evaluation suggest that organic preservation in the midden is poor and so no further excavation of the midden was recommended (Śmiarowski, 2008).

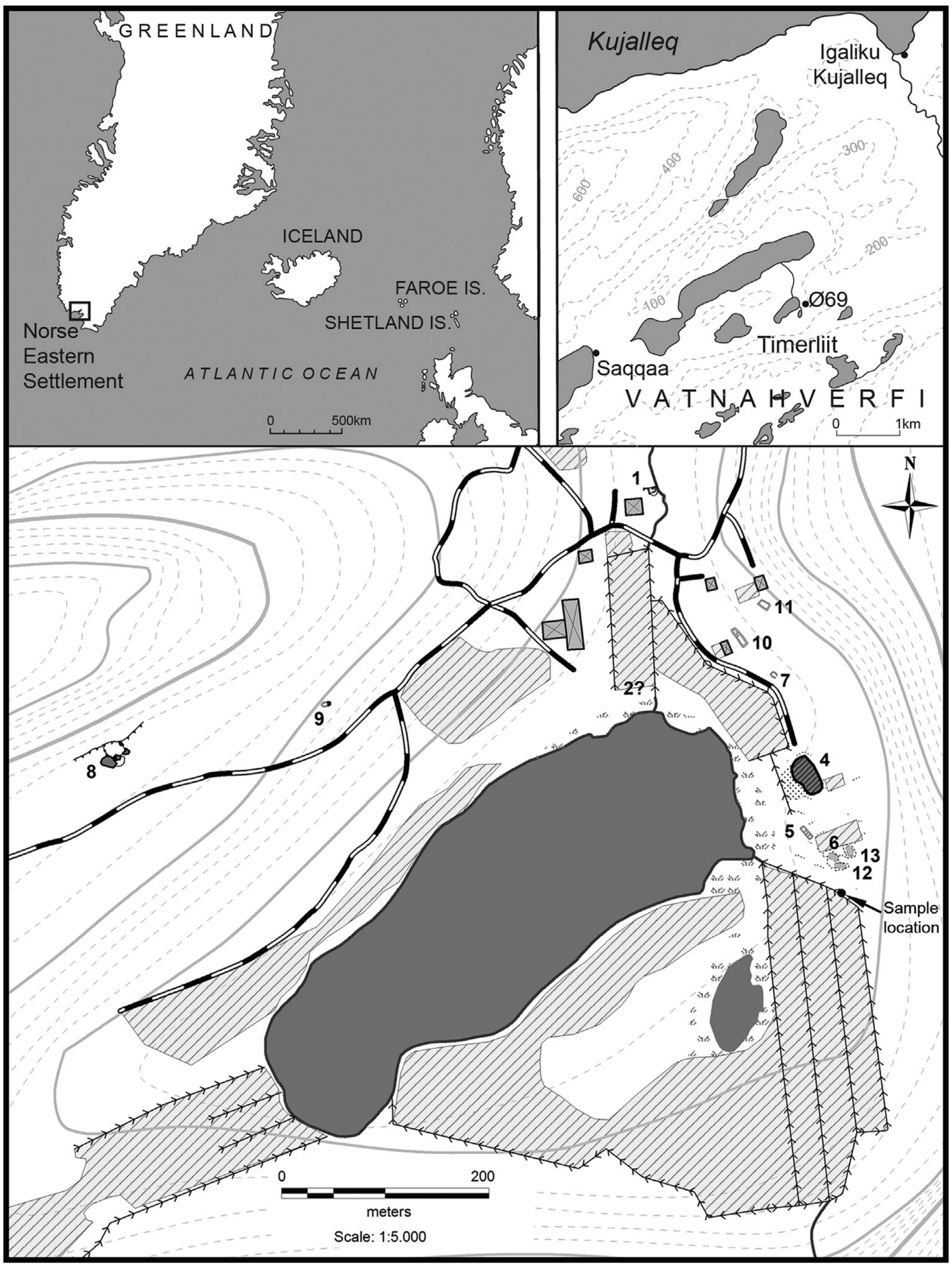

Fig. 1. Location map of Ø69, showing the position of the sampling site in the modern drainage ditch close to the Norse ruins (Numbers 1, 2, 4–13) (N 60.85399141, W 45.30485761). 1: A well-preserved dry stone-built structure of unknown function; 2 and 3 (location unknown): Two structures recorded in the 19th century, but have subsequently been destroyed; 4: Large dwelling structure; 5 and 10: Probable byres/barns; 6–7, 9 and 11–13: Byres/stables/outhouses; 8: Two large enclosures.

Ø69 is located on gently sloping ground and is close to a small lake, rather than the usual fjord-margin location of many Norse sites in the Eastern Settlement. The valley bottom vegetation below the site consists mainly of agricultural fields utilised for hay production. As such it is typical of a favoured non-coastal site with locally significant potential for pastoralism, as shown by the successful modern sheep farm on the site. The modern vegetation on the slopes above the site, and around the hayfields consists mainly of *Salix glauca* L. coll.-*Betula glandulosa* Michx. (Grey willow-American Dwarf Birch) heath. Rich grassland communities and occasional *Salix* (willow) shrubs are present on and around the Norse structures and middens.

2.2. Field methods

During the survey of the Ø69 settlement area in 2005 (Møller and Madsen, 2006), a charcoal-rich horizon was discovered in a drainage ditch of the infield immediately below the main farm site (Fig. 1). This drainage ditch was cut during modern use of the infield and the charcoal-rich horizon was approximately 1 m below the present ground surface. The drainage ditch had largely re-vegetated and the charcoal-rich horizon was only visible within an eroded area, which was approximately 1.5 m long. The charcoal-rich horizon was visible throughout this eroding section. After the section had been cleaned and photographed, three monolith samples and a bulk sample from the charcoal-rich layer (Fig. 2) were taken for radiocarbon, archaeobotanical and sedimentary analyses. The bulk sample was taken using a knife from the immediate area surrounding the monolith sample columns. Each of the samples was wrapped in clingfilm and protective plastic to ensure the samples did not desiccate during transit to the UK. The samples were transported to Geography, School of GeoSciences, University of Edinburgh for laboratory sampling and analysis, where the samples were stored in cold storage (4 °C).

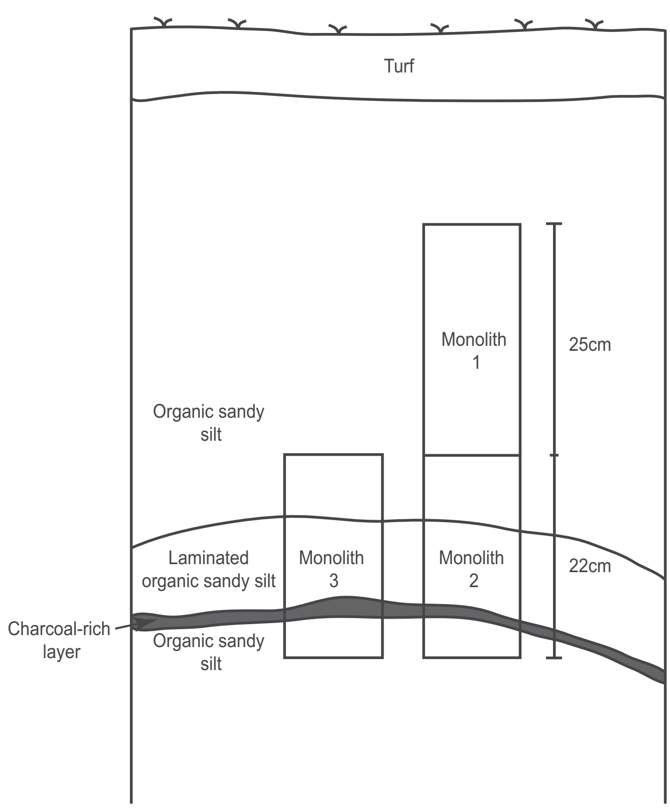

Fig. 2. The drainage ditch section at Ø69, showing the location of the samples and the charcoal-rich layer.

2.3. Laboratory methods

The 1.1 L bulk sample from the charcoal-rich layer was processed using a flotation bucket (Kenward et al., 1980; Pearsall, 2000), with the residue caught in a 1 mm mesh and the flot in a 0.3 mm sieve. The material was air-dried and the flots and residues were fully sorted using a Leica MZ75 stereoscope at 6.3–50× magnification. Charcoal was only sorted from the >4 mm fraction, as identification is very difficult below this size (Pearsall, 2000). Each charcoal fragment was identified to genus, and the total mass of each genus was recorded using a Mettler PM480 Delta Range balance to 3 decimal places. Each fragment was categorised as 'roundwood' if clear curvature was apparent in the ring structure and as 'timber' if no curvature was noted. Caution was exercised when classifying 'timber' in very small fragments, as the degree of curvature was harder to identify. The number of rings was also noted, and the diameter from pith to bark was measured for fragments displaying both a pith and bark in their transverse sections. All plant macrofossil identifications were made using botanical literature (Anderburg, 1994; Beijerinck, 1947; Berggren, 1969, 1981; Hather, 2000; Long, 1929; Schweingruber, 1990) and modern reference material from the Department of Archaeology, University of Durham. Nomenclature follows Böcher et al. (1968).

The monoliths were described and soil colour categorised using Munsell charts (Munsell Color, 1975) before sampling for sedimentary analysis (Table 1). Contiguous 1 cm^3 sub-samples were taken along the length of monoliths 1 and 2 and the organic content of each sub-sample was established through the calculation of the percentage weight loss-on-ignition at 550 °C for 4 h in a Pyrotherm E-Con Chamber Furnace (Heiri et al., 2001). Sub-samples of 16 cm^3 were also taken along the length of monoliths 1 and 2 at 1 cm intervals for basic mineral magnetic analysis. The samples were air-dried, sieved through a 2 mm sieve and the mass-specific magnetic susceptibility (χ) and frequency dependent magnetic susceptibility (κfd%) measured using a MS2 Bartington Susceptibility Meter attached to a Dual Frequency Sensor type MS2b (Dearing, 1994). Charcoal fragments (<2 mm) were also counted from the

Table 1
Descriptions of the sediment at Ø69 (see Fig. 2).

Depth (cm)	Monolith	Description	Munsell color
0–2	1	Organic sandy silt with rare organic material. Lower boundary merges over 0.5 cm.	7.5YR 2.5/2 very dark brown
2–12	1	Organic sandy silt with rare organic material. Mixed mottling evident throughout. Lower boundary merges over 1 cm.	10YR 3/4 Dark yellowish brown
12–20	1	Organic sandy silt with rare organic material. Lower boundary merges over 1 cm.	7.5YR 2.5/2 very dark brown
20–25	1	Organic sandy silt with rare organic material.	10YR 3/3 Dark yellowish brown
25–30	2	Organic sandy silt with rare organic material. Lower boundary clear over 0.25 cm.	10YR 3/3 Dark yellowish brown
30–42	2	Laminated organic sandy silt with rare organics. Very clear lower boundary over 1 mm.	10YR 2/2 Very dark brown
42–44	2	Charcoal-rich silt with small gravel inclusions up to 2 mm in long axis. Very clear lower boundary over 1 mm.	2.5Y 1/1 Black
44–47	2	Organic sandy silt with rare organics.	2.5Y 3/3 Dark Olive brown

sieved residue. The 2 mm dry-sieved sediment was then crushed and pelletised for EDXRF analysis using an Oxford Analytical ED2000 facility.

Two willow (*Salix* sp.) buds retrieved from the charcoal-rich layer were AMS radiocarbon dated at the Scottish Universities Environmental Research Centre (SUERC), with the dates calibrated using IntCal09 (Reimer et al., 2009), within OxCal v4.2.2 (Bronk Ramsey, 2009).

3. Results and discussion

3.1. The date of the Ø69 charcoal-rich layer

The combination and calibration of the two radiocarbon dated willow buds (Table 2) has shown that the charcoal-rich layer was formed between 1262–1382 cal A.D., at least 275 years after the initial *landnám* at the Eastern Settlement (Jones, 1986). The willow buds were recovered from a stratigraphically secure archaeological horizon and there was no evidence that the material had been disturbed by bioturbation. The consistent dates obtained from the two willow buds support this assertion. The dating of willow buds provides a precise date for the layer because the buds represent only a single season's growth, and therefore contain ^{14}C incorporated shortly before the removal/death of the branch. Having said this, as the rate of decomposition of organic material in the North Atlantic is very low, there may be a considerable time lag between the death of the plant and its incorporation within archaeological deposits (Ashmore, 1999; Church et al., 2007a; Sveinbjörnsdóttir et al., 2004). Yet, if this has caused a discrepancy between the true and measured age of the buds, this would increase rather than decrease the time between *landnám* and the creation of the charcoal-rich layer.

3.2. Archaeobotanical identifications and wood exploitation strategies at Ø69

The archaeobotanical sample was dominated by birch (*Betula* sp.) roundwood charcoal, with a smaller proportion of the sample composed of carbonised birch timber and willow (*Salix* sp.) roundwood and leaf buds (Fig. 3, Table 3). Occasional fragments of uncarbonised birch/willow wood, which probably represents contemporary archaeological material preserved by freezing, was also present in the sample. Other tree and shrub species were represented by small quantities of pine (*Pinus* sp.), larch (*Larix* sp.) and fir (*Abies* sp.) timber and alder (*Alnus* sp.) roundwood charcoal, together with a single carbonised alder nutlet. Plant macrofossils from non-woody species were extremely scarce and were represented only by species associated with grassland environments. These consisted of the carbonised remains of a grass (Poaceae undifferentiated) caryopsis, an indeterminate rhizome, several monocotyledon culm nodes and bases and an uncarbonised buttercup (*Ranunculus* sp.) achene. Three small unidentifiable burnt bone fragments were also present in the sample.

Birch and willow charcoal are very difficult to identify to species level on the basis of their anatomical characteristics. For instance, *B. glandulosa* Michx (American Dwarf Birch) does not have any internationally recognised microscopic wood identification criteria (cf. Hather, 2000; Miller, 1975; Schoch et al., 2004; Schweingruber, 1990) and the identification criteria for distinguishing *Betula nana* L. (Dwarf Birch) from *Betula pubescens* Ehrh. coll. (Downy Birch) have not been agreed upon by charcoal specialists. Whilst, Schoch et al. (2004) suggest that *B. nana* L. may be identified by the presence of occasional aggregate rays in the transverse section, Hather (2000) notes that aggregate rays, though rare, may also be present in *Betula pendula* Roth or *B. pubescens* Ehrh. Bhat and Kärkkäinen (1982) also observe that Dwarf Birch often has aggregate rays, but they argue that it can be distinguished from Downy Birch by the increased frequency and small size of the vessels and the narrowness of the growth rings. Whilst all three of these authors state that all *Betula* species are diffuse porous or semi-ring porous, Miller (1975) maintains that *B. nana* L. is ring porous. Thus, due to the lack of an established methodology for distinguishing the birch species native to Greenland and the fact that these species are able to hybridise (Böcher et al., 1968), it was not possible to identify any of the *Betula* fragments in the charcoal assemblage to species level. However, if the wood was locally collected, then the charcoal fragments most probably represent one or both of the two birch species native to this area: the tree-forming species, *B. pubescens* Ehrh. coll. or the dwarf-shrub species, *B. glandulosa* Michx (Böcher et al., 1968; Feilberg, 1984). Considering the small diameter and number of rings of the fragments in the charcoal assemblage (Fig. 3), the charcoal may consist of *B. glandulosa* Michx. branches or they could also represent smaller branches from *B. pubescens* Ehrh. coll. trees.

Likewise, the wood of most willow species cannot be differentiated using microscopic anatomical characteristics (Schoch et al., 2004; Schweingruber, 1990). Whilst some willow species, such as Dwarf Willow (*Salix herbacea* L.) and Grey Willow (*S. glauca* L. coll.) may be identifiable (Miller, 1975; Schoch et al., 2004), the other three species native to Greenland, Bear-berry Willow (*Salix uva-ursi* Pursh.), Northern Willow (*Salix arctophila* Cockerell.) and Arctic Willow (*Salix arctica* Pall.) (Böcher et al., 1968), do not have established identification criteria (cf. Hather, 2000; Miller, 1975; Schoch et al., 2004; Schweingruber, 1990). Consequently, because it was not possible to rule out the presence of any of these species in the assemblage on the basis of their microscopic anatomy and since the willow species native to Greenland are able to hybridise (Böcher et al., 1968), it was not possible to identify any of the charcoal fragments beyond genus level. Yet, since Arctic Willow (*S. arctica* Pall.) is not native to this area of Greenland, the fragments probably originate from one of the other four native dwarf shrubs (Böcher et al., 1968; Feilberg, 1984).

The only other native woody species present in the assemblage was alder. These fragments were probably derived from American Green Alder (*Alnus crispa* (Ait.) Pursh.), which is the only species of alder native to Greenland (Böcher et al., 1968; Feilberg, 1984). However, modern distribution maps indicate that alder is rare (Böcher et al., 1968) or absent (Feilberg, 1984) in Southern Greenland, and so it is also possible that the alder charcoal was derived from a non-local species collected as driftwood.

Table 2
^{14}C dates from Ø69 charcoal-rich layer, calibrated using IntCal09 (Reimer et al., 2009), within OxCal v4.2.2 (Bronk Ramsey, 2009). The combined age was also produced using OxCal v4.2.2, with the χ^2 test results in square brackets.

Reporting code	Sample type	^{14}C age (yr BP $\pm$ 1σ)	Cal AD ($\pm$1σ)	Cal AD ($\pm$2σ)	$\delta^{13}C$ (‰)
SUERC-14049	*Salix* sp. (willow) leaf bud	725 ± 35	AD 1260–1293	AD 1223–1382	−28.1
SUERC-14050	*Salix* sp. (willow) leaf bud	690 ± 35	AD 1275–1381	AD 1261–1391	−30.3
Combined age [*t* value 0.5 (χ^2:0.05 = 3.8)]		708 ± 25	AD 1272–1292	AD 1262–1300 (88.1%) AD 1368–1382 (7.3%)	

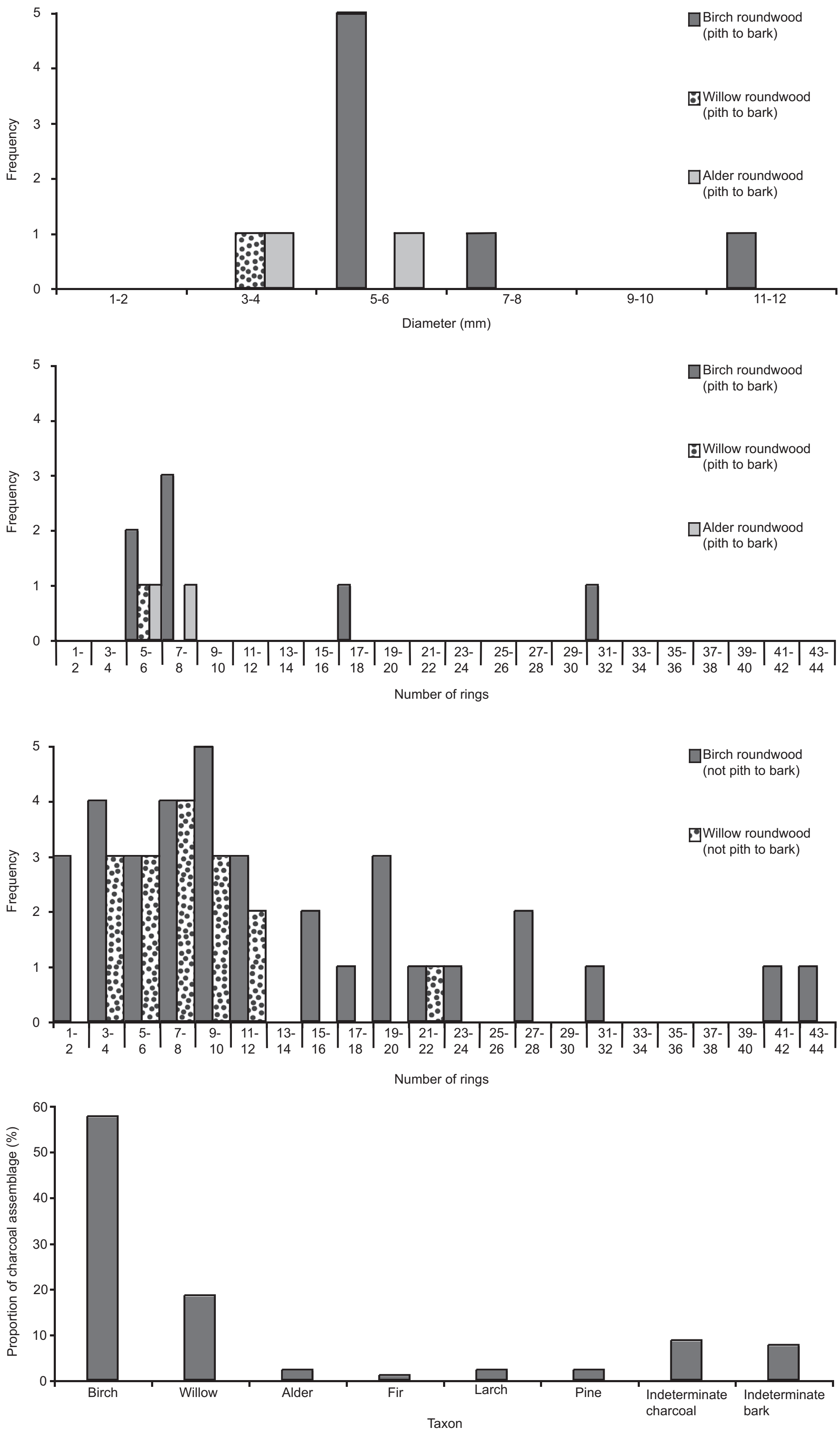

Fig. 3. Proportion of each taxon, ring counts and diameters of roundwood in the charcoal assemblage from the charcoal-rich layer at Ø69.

Table 3
Archaeobotanical identifications from the charcoal-rich layer at Ø69 (F = fragment).

Plant macrofossil identification	Quantification
Charcoal	
Fir (*Abies* sp.) timber	2F (0.04 g)
Alder (*Alnus* sp.) roundwood (pith to bark)	2F (0.04 g)
Birch (*Betula* sp.) timber	8F (0.22 g)
Birch (*Betula* sp.) roundwood (not pith to bark)	38F (1.03 g)
Birch (*Betula* sp.) roundwood (pith to bark)	7F (0.27 g)
Larch (*Larix* sp.) timber	2F (0.02 g)
Pine (*Pinus* sp.) timber	1F (0.03 g)
Willow (*Salix* sp.) roundwood (not pith to bark)	16F (0.3 g)
Willow (*Salix* sp.) roundwood (pith to bark)	1F (0.01 g)
Indeterminate charcoal	8F (0.16 g)
Indeterminate bark fragment	7F (0.09 g)
Total number of fragments identified	92F
Carbonised plant macrofossils	
Alder (*Alnus* sp.) nutlet	1
Grass (Poacaea undifferentiated) caryopsis	1
Willow (*Salix* sp.) leaf buds	2
Fungal sclerotia	3F
Indeterminate rhizome (<2 mm)	1
Indeterminate seeds	2
Monocotyledon culm base	10
Monocotyledon culm node	15
Uncarbonised wood and plant macrofossils	
Birch (*Betula* sp.) bark fragment	9F (0.18 g)
Birch/willow (*Betula/Salix* sp.) uncarbonised roundwood	4F (0.07 g)
Indeterminate uncarbonised wood fragment	1F (0.01 g)
Buttercup (*Ranunculus* sp.) uncarbonised achene	1
Bone	
Burnt bone fragments	3 (0.12 g)

None of the coniferous species recovered in the charcoal assemblage are native to Greenland, and they may have been gathered as driftwood. Modern timber provenancing studies suggest that these coniferous species may have come from the north American continent or Siberia (Bennike, 2004; Dickson, 1992; Eggertsson, 1993; Eurola, 1971; Haggblom, 1982; Johansen, 1999; Johansen and Hytteborn, 2001; Malmros, 1994). Yet, given the scarcity of local large timber-producing species, it is also possible that these non-local coniferous species were imported into Greenland as traded material. This possibility is supported by a contemporary documentary source known as "The King's Mirror", which was written sometime between 1217 and 1260 AD:

> *"And everything that is needed to improve the land must be purchased abroad, both iron and all the timber used in building houses. In return for their wares the merchants bring back the following products: buckskin, or hides, sealskins, and rope of the kind that we talked about earlier which is called 'leather rope' and is cut from the fish called walrus, and also the teeth of the walrus."* (Larson, 1917:142)

In comparison to the sagas relating to Norse Greenland, this source can be considered to be a fairly reliable indicator of the existence of a timber trade between Scandinavia and Greenland because it was written to instruct young men seeking careers in important professions of the day, rather than to act as an entertaining legend or to provide a record of the important historical actors involved in the foundation of Greenlandic society (Larson, 1917:6).

Another potential source of timber was direct importation from North America during the Norse explorations of the area. The collection and transportation of timber from North America to Greenland is frequently mentioned in the "Greenlander's Saga", for example, during Leif Erikson's voyage to Vinland (Jones, 1986). Clearly, given that the Norse sagas were written to entertain rather than to inform, and as they originated as oral folk-tales that were transcribed several hundred years after they were originally composed, they cannot be taken as first-hand accounts of historical events (Jones, 1986; Sigurðsson, 2000). Indeed, it has been argued that the events described were simply stories invented by 13th century Icelandic monks (Jóhannesson, 1962). Yet, given the abundance of worked wood fragments recovered from excavations at the Norse settlement at L'Anse aux Meadows in Northern Newfoundland (Jones, 1986) and the fact that timber collection is mentioned so frequently in the Greenlander's Saga, it is clear that timber procurement was extremely important for Norse Greenlanders. It therefore seems likely – considering the lack of suitable large structural timber producing species in Greenland – that the Norse Greenlanders would have taken advantage of the timber from North American forests during their voyages of discovery for large constructions and for boat building. Considering that larch and fir are not native to Scandinavia (Jalas and Suominen, 1973; Tutin et al., 1964), if they were imported, then they were probably transported from North America (Flora of North America Editorial Committee, 1993+). Pine is native to both Scandinavia (Jalas and Suominen, 1973; Tutin et al., 1964) and North America (Flora of North America Editorial Committee, 1993+) and may have been imported from either continent.

However, the importance of traded wood in Norse Greenland should not be over-emphasised. It is likely that driftwood and larger *B. pubescens* Ehrh. coll. trees would have provided sufficient timber for most smaller constructions. Indeed it has been noted that the Norse built smaller structures with narrower dimensions to compensate for the lack of large native trees suitable for construction (Bruun, 1896). Moreover, the abundance of driftwood in Norse Greenland is indicated by the existence of a driftwood trade between the Inuit in South-West Greenland and the Inuit in the Nuuk fjord area after the end of Norse settlement (Gulløv, 1997) and its continued importance for firewood and construction in the 20th century (Roussell, 1941). The fact that building timbers were often abandoned on Norse sites rather than being reused in other structures (Berglund, 2001; Roussell, 1936, 1941) further supports this point, suggesting that timber was not in short supply.

In fact, though caution must be exercised when interpreting wider regional deforestation from a single archaeological context, the analysis of the Ø69 layer suggests that woodlands/scrub remained significant after the Norse *landnám* in the area. The Ø69 charcoal sample was dominated by native shrub/tree species, such as birch and willow, rather than imported timber or driftwood (Fig. 3), which suggests that local woody taxa remained important fuels into the 13th century AD. The abundance of native tree/shrub species in other Norse archaeobotanical assemblages in Greenland at Qassiarsuk, Sandnes, Sandhavn, Niaqussat, Nipaitsoq and Gården Under Sandet, further supports this interpretation (Andersen and Malmros, 1993; Bishop, 2008; Buckland et al., 1983, 1994; Fredskild and Humle, 1991; Golding et al., 2011; McGovern et al., 1983; Ross, 1997; Ross and Zutter, 2007). The evidence for the continued availability of woodland at Ø69 contrasts with palynological evidence obtained from a mire at Ø70, approximately 1 km away from Ø69, which showed that the local vegetation cover around this site was considerably reduced by the 13th century AD (Ledger et al., 2013). This highlights the complexity of linking archaeological and palynological evidence operating at different spatial and temporal scales to understand wider Norse woodland impact and wood procurement strategies.

Moreover, close examination of the local and regional pollen evidence from South and West Greenland, reveals that woodland/scrub destruction was not widespread at *landnám* and that a complex pattern of vegetation changes occurred between *landnám* and the present day. Recent pollen analyses of peat profiles and lake sequences with high-resolution radiocarbon dating have shown that woodland/scrub clearance at *landnám* was rapid around the

Norse farm site of Ø2 (Edwards et al., 2008) and in the surrounding region of Lake Igaliku in the Norse Eastern Settlement (Gauthier et al., 2010), suggesting a direct human cause for woodland/scrub decline. In contrast, a small reduction in birch woodland/scrub around the Norse farm at Ø39 at *landnám,* was followed by an increase in birch, which was sustained at a relatively high level throughout the Norse settlement, suggesting that woodland/scrub may have been deliberately preserved by the Norse settlers (Schofield and Edwards, 2011). Similarly, a mire core at Ø70 registered only a slight reduction in willow at *landnám* and appears to represent Norse environmental impact on a regional rather than a local scale (Ledger et al., 2013). At this site, woodland/scrub was not substantially reduced around the mire until c. 1050–1150 cal AD (Ledger et al., 2013).

Likewise, wider regional vegetation change appears to be unrelated to anthropogenic action, with either relatively constant (e.g. Kløftsø, Spongilla Sø: Fredskild, 1973; Sârdlup qáqâ: Fredskild, 1983) or gradual and steady declines (e.g. Itivnera: Fredskild, 1973; Terte: Fredskild, 1983), or increases (e.g. Karra, Johannes Iversen Sø: Fredskild, 1983) in arboreal pollen occurring from the period prior to human settlement to the present day. Indeed, though it is difficult to ascribe a late 10th century date to any specific changes in most pollen profiles in the area analysed in the 1970s–1990s (see Section 3.4), the continued presence of relatively high levels of arboreal pollen throughout the Holocene in many regional pollen cores from Greenland (Fredskild, 1973, 1983), suggests that woodlands/scrub survived for a much longer period in the wider landscape outwith the immediate surroundings of the Norse farms.

3.3. The formation of the Ø69 charcoal-rich layer

The wide variety of taxa present in the assemblage suggests that the charcoal was not derived from the burning of shrubs/trees growing *in situ* at the site. The presence of small quantities of uncarbonised wood supports this idea and shows the mixed taphonomy of the assemblage. Furthermore, the presence of three species not native to Greenland – pine, larch, and fir (Böcher et al., 1968) – implies that they must have been introduced into the layer through the anthropogenic discard of traded wood or driftwood because these species could not have been naturally growing in the area.

Since the charcoal assemblage was highly fragmented, few roundwood pieces had pith-to-bark transverse sections, and therefore the range of ages and sizes of wood fragments was difficult to establish. Taken as a whole, though, the assemblage seems to be dominated by small, young pieces of birch and willow roundwood (Fig. 3, Table 3). This could conceivably represent the *in situ* burning of young birch and willow shrubs/trees growing on the site, but considering the presence of the exotic coniferous species this is improbable. It is more likely that the dominance of small young branches represents the residue of fuel burning on a domestic hearth. Equally, the narrow distribution of the number of rings in the local woodland/scrub species may provide evidence for a sustainable woodland/scrub management strategy at Ø69, with the deliberate selection of pieces of branch wood of particular ages or sizes from larger trees/shrubs. Therefore, rather than indicating the deliberate clearance of natural woodlands/scrub, the assemblage seems to reflect the species collected and used by the inhabitants of Ø69 for domestic purposes.

The domestic origin of the assemblage is further supported by the presence of burnt bone, which may represent waste material discarded after human consumption. The small culm nodes, culm bases, fungal sclerotia, the rhizome and the grass caryopsis (Table 3), may be derived from the burning of peat and turf as a fuel (Church et al., 2005, 2007b; Dickson, 1998). Yet, the absence of large volumes of ash and burnt peat and turf remains – the archaeological remains usually recovered from the burning of these common fuels in the North Atlantic region (Church et al., 2005, 2007b; Peters et al., 2004; Simpson et al., 2003) – may indicate that these remains represent the remnants of animal dung (Charles, 1998; Miller and Smart, 1984; Ross and Zutter, 2007) or harvested fodder (Amorosi et al., 1998) accidentally charred on domestic hearths (Ross and Zutter, 2007).

The magnetic susceptibility analysis shows that there was no magnetic enhancement of the charcoal-rich layer at Ø69, which would be expected if *in situ* burning had occurred (Dearing, 1994; Le Borgne, 1955, 1960). Magnetic susceptibility levels remained very low, at less than 1×10^{-8} m^3 kg^{-1} between 35 and 47 cm (Fig. 4, Table 4). The fluctuations in the frequency dependent magnetic susceptibility (κfd%) values between 25 and 45 cm were probably a consequence of the extremely low mass-specific magnetic susceptibility (χ) values at these levels (Table 4; Dearing, 1994). Therefore, it is clear that the charcoal-rich layer was not created through the *in situ* burning of natural vegetation or through the *in situ* burning of fuel on a domestic hearth at the sampling site.

Consequently, considering a) the domestic nature of the archaeobotanical assemblage, b) the absence of associated archaeological features and c) the lack of *in situ* burning, it seems likely that the assemblage formed part of a dump of hearth or midden material from the nearby Norse farm. Given the presence of uncarbonised wood, it seems unlikely that the burnt layer was derived directly from a domestic hearth and it is more likely that it represents the mixing of hearth sweepings and other waste material within domestic middens prior to deposition.

There are several possible mechanisms that could account for the deposition of the midden material in this horizon. Firstly, since the charcoal-rich horizon was found within the infields of the Ø69 settlement, the layer may represent the deliberate addition of midden material to the infields of the Norse farm as part of a soil amendment strategy to increase soil fertility, which was a common practise across the North Atlantic in the Norse period (Adderley and Simpson, 2006; Buckland et al., 2009; Edwards et al., 2013; Golding et al., 2011; Panagiotakopulu et al., 2012; Simpson et al., 2002, 2005). This is supported by the loss-on-ignition results, which show that there was a considerable increase in the organic content at and immediately above the charcoal-rich layer: below 45 cm the organic content was less than 11%, whereas between 31 and 45 cm it was 8–23%, after which it declined to 9% above 45 cm (Fig. 4). This is partly a function of the ignition of the charcoal fragments in the charcoal-rich layer but this would only account for some of the percentage weight loss-on-ignition. The slight enhancement of phosphates and sulphur and the presence of occasional charcoal fragments (<2 mm) at the charcoal-rich horizon and approximately 10 cm above this layer also supports this interpretation (Fig. 4, Table 4).

Secondly, since the exact spatial extent of the charcoal-rich layer is not known, it is possible that the horizon represents a small-scale, localised dump of midden material deposited by the Norse inhabitants of the settlement accidentally or deliberately as a means of refuse disposal. Yet, considering that the nearest structures to the charcoal-rich layer are byres/barns and that the domestic dwelling is nearly 100 m away, it seems unlikely that the inhabitants would have accidentally or deliberately disposed of refuse material this distance from the house. Furthermore, the charcoal-rich layer consists of a distinct, narrow band of material approximately 2–3 cm thick and there is no substantial build up of material indicative of an *in situ* domestic midden. This suggests that multiple deposition events were not involved in the formation of the layer. Field observation shows that the horizon is at least 1.5 m long and as it appears to continue into the revegetated area of the

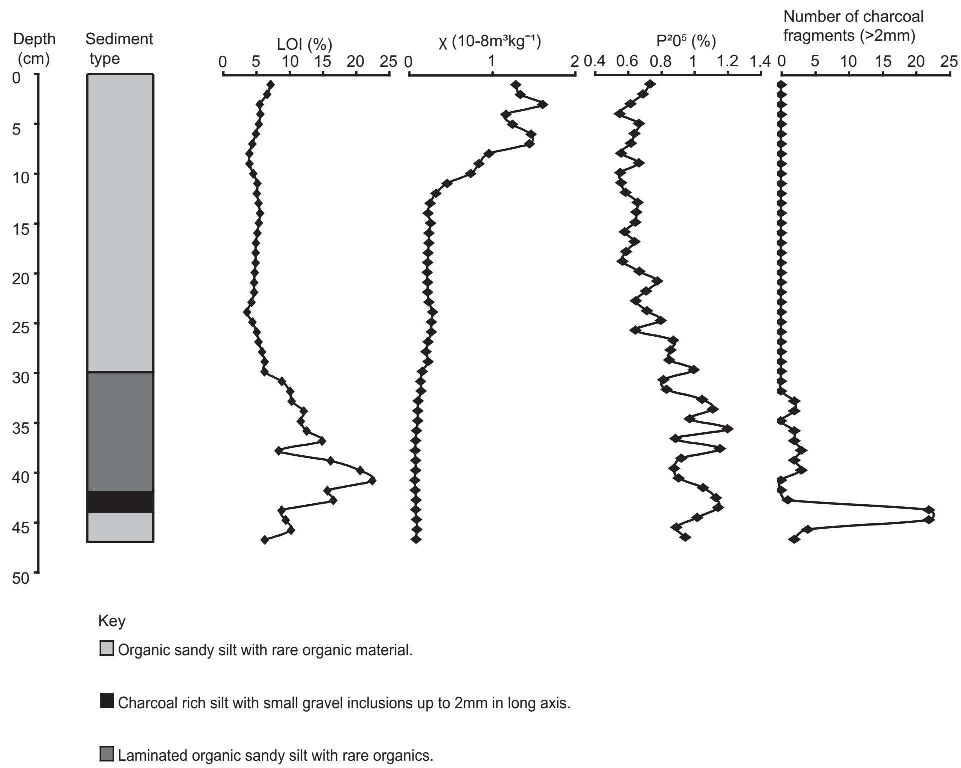

Fig. 4. Sedimentary results from the drainage ditch section at Ø69.

drainage ditch, it seems possible that the horizon may cover a substantial area. Though coring or larger-scale excavation of the drainage ditch section would be necessary to confirm this suggestion, it should be noted that soil amendment in the infields of Norse settlements has been identified in other similar short sections (<1 m) in Greenland, for instance at Sandhavn (Golding et al., 2011). Alternatively, the charcoal-rich horizon may represent a discrete charcoal-rich area within a wider midden deposit, similar to the area of elevated charcoal identified within the amended soils at Igaliku (Buckland et al., 2009).

Thirdly, considering the proposed evidence for soil erosion during the Norse occupation of Greenland (Jacobsen and Jakobsen, 1986; Massa et al., 2012; Sandgren and Fredskild, 1991; Schofield et al., 2010), it is also possible that the material was naturally redeposited from the middens at Ø69 as a result of erosion. However, this seems unlikely considering that only a single distinct charcoal-rich horizon was present in the section and that there is a lack of geomorphological evidence for soil erosion in the site catchment.

Indeed, considering the absence of multiple distinct charcoal-rich layers within the Ø69 section, it is probable that if soil amendment was taking place at Ø69, it was not a practice that continued throughout the use of the site. Though potentially an *in situ* midden deposit, a similar discrete organic and charcoal-rich horizon identified close to the Norse settlement at Eqaluit in the Middle Settlement (radiocarbon dated to 991–1206 cal AD) (Edwards et al., 2013), may also represent discontinuous soil amendment activity, perhaps related to the first settlement of this site.

The potential soil amendment identified at Ø69 might represent a short-lived adaptive response to the environmental changes of the 13th century that took place after the settlement was established at Ø69. This period experienced a series of volcanically-forced cooling episodes, with the largest volcanic perturbation from the 1259 event (Mann et al., 2012). There were also four other moderate to large sulphate injections in 1228, 1268, 1275 and 1285 (Gao et al., 2008). Subsequently there was also a transition to modern conditions of increased summer drift ice in southern Greenland that affected the Eastern Settlement (Jennings and Weiner, 1996). This harbinger of the 'Little Ice Age' seems to have lead to the localised decline in Common seals (*Phoca vitulina*) (Dugmore et al., 2009), and may have stimulated a change in agricultural practice. The subsequent discontinuation of the middening of the infields at Ø69 could be seen as a reflection of the general shift in Norse lifeways during the 13th century (Dugmore et al., 2012), when there was a switch in subsistence emphasis to marine mammals, principally the Migrating harp (*Phoca groenlandicus*) and Hooded seals (*Cystophora cristata*) (Arneborg et al., 1999; Dugmore et al., 2007).

3.4. Dating charcoal-rich horizons

It has been argued that charcoal-rich layers date to the early settlement period in Greenland (Fredskild and Humle, 1991; Iversen, 1934, 1954; Jacobsen and Jakobsen, 1986; McGovern et al., 1988), but as can be seen from Table 5, only 2 charcoal-rich horizons (other than Ø69) have been directly radiocarbon dated. The dates from these two layers support the idea that some charcoal-rich horizons were created during the Norse *landnám*. However, all the other charcoal-rich horizons have been dated relatively, either through association with '*landnám*' vegetation signatures or through stratigraphic relationships with archaeological structures.

However, whilst some pollen sequences from Greenland do have radiocarbon dates that suggest an early date for these vegetation changes (e.g. Ø2: Edwards et al., 2008; Ø34: Schofield and Edwards, 2011), most Greenland pollen diagrams taken in the 1970s–1990s have very few radiocarbon dates along their sequences, particularly in the key period between 900 and 1300 cal AD (Fredskild, 1973, 1978, 1988). Where radiocarbon dates are

Table 4
Loss-on-ignition, χ, κfd% and selected EDXRF results from Ø69 (proportions corrected against organic content).

Depth (cm)	LOI (%)	χ (10^{-8} m^3 kg^{-1})	κfd%	P^2O^5 (%)	S (%)
0–1	7.21	1.29	1.0	0.737	0.082
1–2	6.67	1.35	0.8	0.692	0.031
2–3	5.54	1.61	0.1	0.619	0.051
3–4	5.65	1.17	1.5	0.552	0.005
4–5	5.43	1.25	1.8	0.670	0.031
5–6	4.99	1.48	0.9	0.643	0.029
6–7	4.45	1.46	1.2	0.620	0.002
7–8	4.00	0.97	1.4	0.562	0.000
8–9	3.99	0.85	2.8	0.669	0.025
9–10	4.59	0.75	2.2	0.556	0.000
10–11	5.21	0.46	2.6	0.561	0.000
11–12	5.11	0.33	2.7	0.587	0.012
12–13	5.39	0.26	2.8	0.661	0.000
13–14	5.59	0.23	3.4	0.652	0.000
14–15	5.42	0.26	4.0	0.647	0.005
15–16	5.21	0.25	1.3	0.583	0.000
16–17	5.00	0.24	6.5	0.641	0.006
17–18	4.93	0.24	3.6	0.591	0.009
18–19	4.95	0.23	0.2	0.570	0.000
19–20	4.79	0.23	3.2	0.671	0.001
20–21	4.71	0.23	5.1	0.778	0.000
21–22	4.73	0.23	5.2	0.711	0.018
22–23	4.30	0.24	3.7	0.651	0.027
23–24	3.63	0.29	3.6	0.716	0.031
24–25	4.47	0.28	5.7	0.800	0.000
25–26	5.11	0.27	2.9	0.646	0.027
26–27	5.37	0.23	2.8	0.875	0.032
27–28	5.92	0.21	3.5	0.860	0.020
28–29	6.31	0.24	3.4	0.852	0.057
29–30	6.26	0.16	2.8	1.000	0.038
30–31	8.91	0.14	2.6	0.816	0.077
31–32	10.12	0.15	3.0	0.835	0.034
32–33	10.37	0.12	0.6	1.051	0.104
33–34	12.18	0.11	1.9	1.115	0.186
34–35	11.75	0.11	8.2	0.974	0.124
35–36	12.65	0.10	5.5	1.204	0.291
36–37	14.94	0.09	0.0	0.889	0.165
37–38	8.42	0.08	7.8	1.158	0.384
38–39	16.26	0.08	3.9	0.925	0.306
39–40	20.68	0.09	2.4	0.882	0.234
40–41	22.51	0.07	9.9	0.908	0.463
41–42	15.73	0.08	7.0	1.057	0.436
42–43	16.64	0.09	1.8	1.134	0.348
43–44	8.87	0.08	9.2	1.146	0.323
44–45	9.47	0.09	6.2	1.022	0.217
45–46	10.29	0.10	6.3	0.895	0.111
46–47	6.31	0.09	6.5	0.949	0.151
Mean	**7.89**	**0.4**	**3.5**	**0.794**	**0.096**
St dev	**4.56**	**0.45**	**2.4**	**0.190**	**0.129**
Min	**3.63**	**0.07**	**0.1**	**0.552**	**0.000**
Max	**22.51**	**1.61**	**9.9**	**1.204**	**0.463**

available, their precision is limited by the presence of a small plateau in the calibration curve between c. 850–1000 AD (Reimer et al., 2009). The reliability of the radiocarbon dates from some pollen sites is also open to question, because radiocarbon-dated peat samples may incorporate an ‘old carbon’ error (Edwards et al., 2008; Schofield et al., 2008, 2010). Thus, detailed analysis of the exact timing of vegetation change is very difficult to assess and many woodland/scrub reductions visible in pollen diagrams and ‘associated’ charcoal-rich horizons may have occurred considerably later than the 10th–11th century AD.

Direct archaeological associations are perhaps more secure. For instance, charcoal-rich horizons have been identified beneath the Norse structures at the Norse settlement at Ujarassuit (Table 5). Yet, only broad dates are available for these structures and it is not clear how long before the Norse structures were constructed that the charcoal layers formed.

Indeed, while the late 10th century date of the Norse colonisation of Greenland is not disputed, it is probable that Norse settlement was not simultaneous and there may have been a number of local Norse *landnám* events and settlement episodes which occurred at different times across Greenland as populations moved and exploited new areas. In this regard the development of the Norse settlement in Greenland may be quite different to that of Iceland. While there is increasing evidence that the colonisation of Iceland was abrupt and extensive (McGovern et al., 2007; Vésteinsson and McGovern, 2012), likely differences in settlement motivation and the increased difficulty of voyages west of Iceland may suggest that Norse settlement across the Eastern and Western settlements was much more gradual and of a different character (Dugmore et al., 2007). Moreover, during the centuries of Norse settlement in Greenland, the focus of subsistence changed from pastoralism to a diet primarily based on marine mammals, principally seal (Arneborg et al., 1999; Dugmore et al., 2009; Nelson et al., 2012). This shift in subsistence strategy could have caused a change in settlement pattern, aimed at reducing journey times to crucial offshore seal culling sites while still maintaining farms.

Thus, whilst there is evidence that charcoal-rich horizons may mark the initial use of a site during the early Norse occupation of Greenland in some instances, it cannot be assumed that all such layers were created during the Norse *landnám*. Indeed, given the complexity of the dynamics of Norse settlement, it seems unlikely that there ever was a single *landnám* woodland/scrub clearance event that exists to be recognised as a homogeneous “burning” layer in soil and sediment sections across Greenland. The 13th–14th century date of the layer at Ø69 suggests that many undated “*landnám* burning horizons” may have been wrongly categorised and without further sampling, dating and analysis of the archaeobotanical composition of these layers, they cannot be assigned to a generalised time period.

3.5. Charcoal-rich layers and vegetation burning

It has been suggested that many charcoal-rich horizons in Greenland were created through *in situ* vegetation burning (Amorosi et al., 1997; Dugmore et al., 2005; Fredskild, 1973, 1988, 1992b; Fredskild and Humle, 1991; Iversen, 1934, 1954; Jacobsen and Jakobsen, 1986; McGovern et al., 1988). However, in an environment where shrubs/trees were neither large, plentiful nor fast-growing (Böcher et al., 1968; Elkington and Jones, 1974), it is debatable that the Norse would have used fire to clear all areas of scrub and woodland. Axes could have been used for woodland and vegetation clearance so that the wood could be utilised. Indeed, Fredskild (1978, 1981) argues that axes were used to clear the vegetation at Qassiarssuk, because of the relative abundance of wood chips compared to charcoal in many of the investigated horizons. Wood is an extremely versatile and important raw material for farmers and it was used for numerous purposes by the Norse across the North Atlantic islands, including fuel, artefact manufacture, furniture, building construction, boat building, fencing, roofing, flooring, animal fodder and charcoal production for metal working, as shown by archaeobotanical assemblages across the Norse Atlantic (Bishop, 2008; Church et al., 2005; Fredskild and Humle, 1991; Malmros, 1994; McGovern et al., 1983, 1988; Ross, 1997; Ross and Zutter, 2007; Sveinbjarnardóttir et al., 2007; Vickers et al., 2005; Zutter, 1992, 1999). However native willow/birch scrub could only be used for some of these purposes, for example fuel, fodder, artefact manufacture, small structures and flooring, but not for larger building constructions or boat building. Therefore, rather than destroying this essential resource, it seems likely that the Norse would have preserved and managed woodlands/copses, as suggested by the on-site archaeobotanical

Table 5
Horizons interpreted as representing *in situ landnám* vegetation burning by the authors of the reports listed. The radiocarbon date from Sandnes Section VII was calibrated using IntCal09 (Reimer et al., 2009), within OxCal v4.2.2 (Bronk Ramsey, 2009).

Site	Location	Site type	Dating method	Associated vegetation changes	Reference
Igaliku Kujalleq	South Greenland	Natural soil profile	Charcoal layer radiocarbon dated to 900–1000 AD (no information on calibration given)	Pollen from the natural soil profile: reduction in willow	Jacobsen and Jakobsen 1986
Kapisilik	Godthåbsfjord area, West Greenland (64′°26′N, 50°12′W)	Bog profile near Norse farm at Kapisilik	Not dated	Pollen core from a lake close to the Norse farmstead – increase in microcharcoal, grasses and herbs and a decline in alder and willow	Fredskild 1973: 148; Iversen 1954: 93-4
Sandnes Section VII	Approximately 1 km North of Sandnes, Kilaarsarfik, Western Settlement	Fen profile	Charcoal layer radiocarbon dated to 890 ± 70 uncal BP = 1023–1260 cal AD (95.4%)	Pollen from the fen profile – reduction in dwarf shrubs of birch, willow and alder, increase in *Rumex acetosella* L.	Fredskild and Humle 1991
Ujarassuit moor	Ujaragssuit, Godthaabfjords, Western Settlement (65′°50′N, 50°08′W)	Moor profile	Not dated	Pollen from the moor profile – grasses and *Rumex* sp. rapidly increase, shrubs and dwarf-shrubs decline	Iversen 1934; Fredskild 1972, 1973: 163-4
Ujarassuit settlement	Godthaabfjords, Western Settlement	Charcoal layer underlying Norse church at the Norse settlement at Ujarassuit	Charcoal-rich layer underlies the church in the Norse settlement	Pollen from the moor profile at Ujarassuit – grasses and *Rumex* sp. rapidly increase, shrubs and dwarf-shrubs decline	Iversen 1934; Fredskild 1972, 1973: 163-4
Umiviarssuk	At the head of Ameralik, Western Settlement (64′°14′N, 50°10′W)	Moor profile	Not dated	Same result as Ujarassuit Moor	Iversen 1934

evidence in Norse and early Medieval Iceland and Greenland (Bishop, 2008; Church et al., 2007a; Lawson et al., 2007).

Moreover, though there are several instances in which charcoal-rich horizons (see Table 5) or microcharcoal increases are chronologically correlated with woodland/scrub declines in pollen sequences (e.g. Ø2: Edwards et al., 2008; Comarum Sø: Fredskild, 1973; Johannes Iversen Sø: Fredskild, 1983; Lake 8 m s.m.: Iversen, 1954; Galium Kaer: Sandgren and Fredskild, 1991; Ø70: Ledger et al., 2013), there is not necessarily a direct correlation between these phenomena. Firstly, microcharcoal may originate from domestic hearths and charcoal production pits associated with Norse settlement rather than from *in situ* vegetation burning (Edwards et al., 2008: 10; Schofield and Edwards, 2011: 189; Schofield et al., 2008: 9). The fact that microcharcoal increases are often sustained throughout most of the Norse settlement period (e.g. Ø2: Edwards et al., 2008; Lake 8 m s.m.: Fredskild, 1973; Johannes Iversen Sø: Fredskild, 1983; Ø39: Schofield and Edwards, 2011; Ø70: Ledger et al., 2013) rather than just at *landnám* supports this suggestion, and probably reflects the continuous use of domestic fires, rather than isolated vegetation burnings. Secondly,

Table 6
Calibrated radiocarbon dates from horizons containing charcoal scatters in Greenland identified by Jakobsen (1991), Golding et al. (2011), Buckland et al. (2009) and Edwards et al. (2013), which may provide evidence for Norse soil amendment. Radiocarbon dates calibrated using IntCal09 (Reimer et al., 2009), within OxCal v4.2.2 (Bronk Ramsey, 2009).

Site	Sample details	RC age BP	Calibrated date (95.4% probability)	Reference
Ø66	Charcoal fragments from lower part of the A horizon	1030 ± 70	784–1175 cal AD	Jakobsen 1991
Ø75	Charcoal fragments from lower part of the A horizon	1081 ± 80	724–1155 cal AD	Jakobsen 1991
Ø168	Charcoal fragments from lower part of the A horizon	1091 ± 85	709–1154 cal AD	Jakobsen 1991
Ø294	Charcoal fragments from lower part of the A horizon	1116 ± 85	685–1147 cal AD	Jakobsen 1991
Ø68	Charcoal fragments from middle of the A horizon	725 ± 65	1171–1396 cal AD	Jakobsen 1991
Ø64a	Charcoal fragments from middle of the A horizon	781 ± 65	1046–1385 cal AD	Jakobsen 1991
Ø73	Charcoal fragments from middle of the A horizon	836 ± 85	1024–1288 cal AD	Jakobsen 1991
Ø64c	Charcoal fragments from upper part of the A horizon	656 ± 55	1269–1406 cal AD	Jakobsen 1991
Ø64a	Charcoal fragments from upper part of the A horizon	596 ± 65	1283–1430 cal AD	Jakobsen 1991
Ø67	Charcoal fragments from upper part of the A horizon	571 ± 65	1289–1439 cal AD	Jakobsen 1991
Ø221	Willow charcoal fragment from Ap horizon (profile 1)	645 ± 30	1281–1396 cal AD	Golding et al., 2011
Ø221	Willow charcoal fragment from Ab horizon (profile 2)	880 ± 30	1042–1221 cal AD	Golding et al., 2011
Ø221	Birch charcoal fragment from Ap horizon (profile 3)	900 ± 30	1040–1211 cal AD	Golding et al., 2011
Ø221	Birch charcoal fragment from Ap2 horizon (profile 4)	790 ± 30	1188–1280 cal AD	Golding et al., 2011
Ø221	Birch charcoal fragment from Ap1 horizon (profile 4)	670 ± 30	1274–1391 cal AD	Golding et al., 2011
Igaliku	Plant macrofossils from base of 'plaggen' deposit (containing charcoal, worked wood, animal bone)	875 ± 35	1040–1251 cal AD	Buckland et al., 2009
Igaliku	Plant macrofossils from upper 'plaggen' deposit (containing charcoal, worked wood, animal bone)	625 ± 35	1289–1400 cal AD	Buckland et al., 2009
M10	Charred twig from a black organic-rich horizon	985 ± 30	991–1154 cal AD	Edwards et al., 2013
M10	Charcoal fragment from a black organic-rich horizon	915 ± 30	1031–1206 cal AD	Edwards et al., 2013

whilst human impact was clearly responsible for woodland and scrub decline in Greenland during and after the Norse *landnám*, charcoal-rich horizons may have been created as a result of a number of other anthropogenic activities. For example, as with Ø69, they may represent deliberate soil amendment strategies to fertilise the infields, or they could also represent *in situ* hearths or areas of redeposited midden.

The presence of woodchips as well as charcoal in the sample from Ø69 and the horizon excavated at Ujarassuit moor, together with partly burnt twigs in the Sandnes charcoal-rich horizon (Table 5), also supports this contention, suggesting a domestic origin for many such layers rather than the *in situ* burning of shrubs/trees. Similar layers and concentrations of uncarbonised and carbonised wood have been frequently noted during the excavation of Norse sites in Greenland in middens, houses and byres (Buckland et al., 1994; McGovern et al., 1988; Nörlund and Stenberger, 1934; Roussell, 1936, 1941). For instance, wood and charcoal assemblages from the Norse farm at Sandnes, located in the Western Settlement (Andersen and Malmros, 1993; Buckland et al., 1994; Fredskild and Humle, 1991) and Qassiarsuk in the Eastern Settlement (Bishop, 2008) contained a mixture of native (willow, birch, alder, juniper) and non-native (oak, elm, larch, fir, pine and spruce) uncarbonised wood and charcoal fragments. The other 4 site assemblages with archaeobotanical identifications from Greenland (Niaqussat, Nipaitsoq, Gården Under Sandet and Sandhavn) also contained a mix of carbonised and uncarbonised remains, but only provide evidence for the exploitation of native species, such as birch, willow, alder and juniper (Buckland et al., 1983; Golding et al., 2011; McGovern et al., 1983; Ross, 1997; Ross and Zutter, 2007). Therefore, considering the similar mix of carbonised and uncarbonised native/non-native wood species in domestic archaeobotanical assemblages and in off-site charcoal-rich horizons, it seems likely that many of these off-site horizons are actually accumulations or dumps of anthropogenic midden material. This suggestion is further supported by the frequent occurrence of charcoal fragments scattered (rather than as distinct layers) within the A horizons of soil profiles in the infields of Norse settlements (Golding et al., 2011; Jakobsen, 1991). As with the material in the section at Ø69, this material may be derived from the middening of the infields as a soil amendment strategy or from eroded midden deposits. Radiocarbon dating of the charcoal fragments from these horizons, together with the radiocarbon dates associated with probable soil amendment identified at other sites in Greenland (Table 6), suggests that middening was a practice that occurred throughout the Norse settlement period (Golding et al., 2011).

4. Conclusion

The analysis of the charcoal-rich horizon at Ø69 has enhanced understanding of the wood procurement strategies utilised at this site and the taphonomy of the archaeobotanical assemblage. It has been demonstrated that the charcoal-rich layer at Ø69 was not derived from the *in situ* burning of natural woodlands/scrub in the 10th century to create agricultural land. The absence of magnetic enhancement of the layer, the mixed nature of the charcoal assemblage, the presence of uncarbonised wood, burnt bone and driftwood/traded timber, together with the increase in organic content of the soil and slight enhancement in phosphates and sulphur, suggests that the material was derived from a domestic midden, and may have been added to the infields around Ø69 as part of a soil amendment strategy to increase soil fertility. This shows that caution must be exercised when interpreting charcoal-rich horizons as time-specific chronological markers in palaeoenvironmental sequences in Greenland and that further sampling, dating and analysis of the archaeobotanical composition of identified charcoal-rich horizons is required to establish whether *landnám* vegetation burning was widely responsible for creating such layers in the vicinity of Greenland Norse settlements.

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